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SPACE POWER OPERATION

MONTHLY PROJECT STATUS REPORT

July 31, 1961

(NASA CR 52537)

HEAT TRANSFER DEVELOPMENT PROGRAM

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NUMBER NAS 5-681

FLIGHT PROPULSION LABORATORY DEPARTMENT

GENERAL ELECTRIC COMPANY

CINCINNATI 15, OHIO

3524006

MONTHLY PROJECT STATUS REPORT

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EXPERIMENTAL PROGRAM

Test Sections. The machining of the test section component parts has largely been completed for Boiler #1, Condenser #1 and #2. Welders have been qualified for L-605 to the standards required by the project specifications. Welding of the test sections is proceeding on certain subassemblies. The lack of several critical pieces may delay completion of the test section. The limiting items are L-605 tubing and the Mo-0.5 Ti alloy tubing. The L-605 pieces have been delayed due to rejection of a hollow tube which did not meet specifications. A new hollow tube has been processed and is ready for rocking to finish size at Michigan Tube. The vendor attempted to draw the Mo-0.5 Ti tubing using stock dies and mandrels not suitable for this alloy. Difficulty was encountered with two hollows before the proper corrective action was taken. New tooling has been procured and the drawing process and heat treat are under surveillance by FPLD materials engineers. The first tube to be produced will be trimmed and two sample joints prepared. These joints will be thermal cycled to determine the acceptability of the joint design and the tubing. If the cycling test is favorable the Mo-0.5 Ti tube will be used. A back-up L-605 tube is on hand and can be used in the event it is required.

The expansion bellows for the boiler test section have passed the static tests and one sample will be cycle tested during August. The test conducted to date included pressure tightness and deformation at 1800 ^{o}F with 100 psi external pressure. Mass spectrometer test results prior to and following the pressure test were better than MIL-STD 271 A requirements.

The horizontal and vertical condensers for the 50 KW test system have been completed. These test sections are .6263 and .2647 inches I.D. respectively. Data will be obtained at temperatures up to 1600^{o}F on these units to supplement the data to be obtained in the 300 KW test system.

A preliminary test plan has been worked out for the 50 KW test system to cover approximately 30 runs. These runs will be set up by establishing first the boiler heat input and the liquid metal flow rate. The pressure at the condenser inlet will be established by air cooling conditions and the throttle valve. It is planned to run all tests for the horizontal unit and a representative selection of tests for the vertical unit. After completion of these tests suitable inserts will be tested. An investigation of insert details is underway and several designs will be selected in the next month.

Instrumentation

Thermocouple procurement for the several types of data temperature measurements has been initiated. Several sizes of Pt-Pt 10 Rh alloy have been ordered as well as nichrome and L-605 sheath materials for the 300 KW Test System. High purity MgO will be used for the insulators. The difficulties in making a suitable swaged W-W-26 Re thermocouple have precluded its use. In the 100 KW system swaged elements will not be required and the W-W-26 Re will be used.

Preliminary pressure drop measurements will be made with the diaphragm pressure instruments in the 50 KW test loop. Five of these instruments have been procured and will be installed to obtain measurements up to 1600°F.

A magnetic flux meter and reference standard have been procured to calibrate the permanent magnets of the electromagnetic flowmeter. This device will be used first on the flowmeter for the 50 KW loop. It is expected to be able to determine flux density to ± 1%. Such calibration will be performed on a periodic basis to assure continuous measurement precision.

Arrangements have been made to set up the X-ray densitometer in conjunction with the 50 KW test. Observations will be made for liquid and liquid/vapor mixtures. These measurements should give an indication of the sensitivity of the device and any improvements required may be detected before operation of the 300 KW test.

Test Plan . Several requests have been made for thesis results on film boiling heat transfer data to correlate with the mixing length analysis. It is now recognized that liquid metal results may be difficult to correlate due to the lack of the transport property data, particularly vapor viscosity and thermal conductivity. The existing results by Weatherford have been reviewed and some modification to these methods will be utilized to obtain new analytical results. The need for either viscosity or thermal conductivity measurements for potassium and sodium vapor is therefore most urgent for correlation.

MATERIALS SUPPORT

L-605 Aging Investigation

Study of the aging behavior of L-605 is continuing, and additional data has been obtained concerning (1) the influence of the cooling rate on the aged ductility, (2) the effect of pre-aging heat treatments and aging on the mechanical properties at elevated temperature, and (3) the effect of pre-aging heat treatments and aging on the ductility after prolonged exposure to potassium. In addition, several different heats of L-605 are being investigated. Previously, all sheet specimens used for corrosion and aging tests were from heat No. 30801, except for the specimens of specially prepared low carbon material.

The data in Table I indicates that slow cooling from the aging temperature of 1600°F can result in slightly better room temperature ductility than rapid cooling. This suggests that some unknown reaction, in addition to the sluggish precipitation of Co_2W, may occur and influence the aged ductility to a limited extent. If the effect of cooling rate applies over the entire time-temperature range of aging, it could be advantageous because slow cooling will generally be applied during loop operation.

TABLE I

THE EFFECT OF COOLING RATE ON THE DUCTILITY OF L-605

AFTER AGING FOR 100 HOURS AT 1600°F *

	F.C.	A.C.	W.Q.
1.5 T Bend Test at Room Temp.			
Heat L-1693 (.156" thick)	22°	12°	13°
Heat L-1202 (.064" thick)	37°	31°	39°
Heat 30801 (.064" thick)	56°	49°	39°
Tensile Test at Room Temp.			
Heat L-1202			
U.T.S. psi	156,700	157,800	154,300
0.02% Y.S. psi	68,400	69,800	59,700
0.2% Y.S. psi	83,800	85,600	88,800
% Elong. in 1"	15.3	11.8	11.8

* The initial material was solution annealed prior to aging.

Tensile and stress rupture data have been obtained at 1600°F with material aged for 1,000 hours at 1600°F, following the solution anneal at 2250°F and following a pre-aging anneal of 4 hours at 2100°F (Tables II and III). The rupture life of all the specimens is well within design expectations, and significant ductility was obtained in the rupture and tensile tests. Use of the pre-aging anneal at 2100°F after the usual solution anneal appears to improve the rupture ductility significantly, without greatly reducing the rupture strength. The same treatment results in a slight improvement in the already adequate tensile ductility and notched to unnotched ratio of the tensile strength.

TABLE II

1600°F LIFE TO RUPTURE AT 15,000 PSI

Ht. L-1695, Solu. H.T. + 1,000 hrs. at 1600°F, A.C.	108.7 hrs.	18% Elong. in 1"
20% C.W. Material, *H.T. 4 hrs. 2100°F + 1,000 hrs. at 1600°F, A.C.	96.8 hrs	22% Elong. in 1"
Ht. L-1695, Solu. H.T. + 4 hrs. 2100°F + 1,000 hrs at 1600°F, A.C.	80.9 hrs	31% Elong. in 1"

* Samples supplied by the Haynes Stellite Co. from a special heat for which in-process anneals were below 2100°F.

TABLE III

1600°F TENSILE DATA ON AGED L-605

	20% C.W. Material*, Solu. H.T. + 1,000 hrs. at 1600°F, A.C.		20% C.W. Material*, Solu. H.T. + 4 hrs. 2100°F Anneal + 1,000 hrs. at 1600°F, A.C.	
	Unnotched	Notched**	Unnotched	Notched**
U.T.S. psi	39,500	55,200	37,900	60,400
0.02% Y.S. psi	22,950	-	24,700	-
.20% Y.S. psi	26,150	-	30,150	-
% Elong. in 1"	41	-	46	-

Ratio $\frac{\text{U.T.S. notched}}{\text{U.T.S. unnotched}} = 1.4$ Ratio $\frac{\text{U.T.S. notched}}{\text{U.T.S. unnotched}} = 1.6$

* Samples supplied by Haynes Stellite Co. from a special heat for which in-process anneals were below 2100°F.

** Sheet specimens; notch radius 0.005", notch depth 0.070" per side, unnotched width 0.303".

Additional data describing the aging behavior are being obtained from specimens exposed to potassium in a recent set of static capsule tests, and the bend test results are included in Table IV. Specimens which received a pre-aging treatment at 2100°F are significantly more ductile than solution annealed specimens after subsequent annealing at lower temperatures; however, it is also apparent that the pre-aging treatment did not completely stabilize the material with respect to subsequent aging embrittlement at lower temperatures. Relatively low values of ductility are indicated, even with the pre-aging treatment.

Comparing the bend test results in Table IV with those previously reported for capsule tests, it is particularily apparent that the decrease in ductility during 1,000 hours at 1700° and 1850°F is greater in the present case. The test specimens were obtained from different heats of L-605 in each case, and this may account for the difference in aging response.

Additional experiments are in progress to document the properties of aged material and to investigate the effect of pre-aging treatments on several heats of L-605.

TABLE IV

RESULTS OBTAINED FROM L-605 SPECIMENS EXPOSED TO POTASSIUM(1)

Temp., °F	Time, Hrs.	Liner (2)	Wt. Loss % (3) Avg. 3 to 4 Spec.	1.5 T Bend Angle at Room Temp.	
1850	100	None	0.035	62^o (4)	106^o (5)
1850	1000	None	0.048	100^o	--
1850	1000	20 in^2 Cb-1Zr	Capsule Failed	76^o	98^o
1700	100	None	0.021	41^o	--
1700	100	20 in^2 Cb-1Zr	0.019	39^o	--
1700	1000	None	0.039	35^o	87^o
1700	1000	20 in^2 Cb-1Zr	0.091	40^o	82^o
1550	100	None	0.022	51^o	--
1550	100	20 in^2 Cb-1Zr	0.010	34^o	--
1550	1000	None	0.029	27^o	62^o
1550	1000	20 in^2 Cb-1Zr	0.029	30^o	53^o

(1) L-605 capsules: 1.165" O.D. x 0.063" wall x 5" long. About 28 gms. of potassium purchased as slagged, filtered, distilled, and hot trapped and subsequently hot trapped with Zr at 1400°F at FPLD.

(2) Cb-1Zr: 20-mil sheet, total surface area reported.

(3) L-605 heat No. L-1695: total tensile and bend specimen surface area about 9.5 in^2 for capsules with one bend specimen and about 11.5 in^2 for capsules with two bend specimens.

(4) Initial material, solution annealed at 2250°F, 63-mil sheet.

(5) Initial material, solution annealed at 2250°F, cold worked 20%, and annealed for 4 hrs. at 2100°F, 50-mil sheet.

Potassium Environmental Effects

Several static capsule tests have been completed recently, and evaluation of the test specimens is in progress. These tests were conducted to obtain more extensive data describing the behavior of (1) Cb-1Zr as a getter material, (2) L-605 in the absence of a getter material, and (3) L-605 specimens from a different heat of material and with a pre-aging heat treatment. Preliminary examination is generally indicative of mild corrosion, and the L-605 weight loss is somewhat less than that observed in the previous capsule tests. The bend tests results are described in the preceding section.

One of these capsules failed between 800 and 1,000 hours at 1850°F. It had a 0.01-inch dia. penetration and accompanying corrosive attack of the O.D. surface over a larger region (about 0.3-inch dia.) at a location removed from the closure welds. The number of successful tests conducted under similar conditions and the local nature of the attack in this case suggest that the failure occurred at a defective region in the L-605. This tubing was purchased at the beginning of the program from available stock without extensive inspection, and there was visual evidence that the tube had been severely contaminated in a few spots during heat treatment. It is possible that one of these contaminated regions passed visual inspection, leading to the capsule failure. Metallographic examination, however, has not provided conclusive evidence of defective material, and it appears doubtful that a good understanding of this failure will be obtained.

Evaluation of the L-605 thermal convection is continuing:

1. The L-605 tubing in the cooling leg has been leak tested with helium and found to be leak tight.

2. Metallographic examination of the L-605 heater tube at the points of arcing indicates that melting did not extend completely through the tube wall.

3. The weight loss of the L-605 strip specimen in the heater leg was 0.0008%. Expectations are that interstitial element transfer alone would have contributed to a larger weight decrease.

Additional evaluation of the loop and contained specimens is in progress.

Joining L-605 to Molybdenum

Three 0.5-inch O.D. Mo-0.5 Ti to L-605 tube joint specimens were vacuum induction brazed successfully, and two of these are being prepared for thermal cycling tests in potassium. When the 1-inch O.D.

Mo-0.5 Ti tubing is received, additional joints will be brazed and evaluated, preparatory to using this tubing for the 300 KW loop heat transfer test section.

100 KW Test Section Development

For development of a radiation heated test section, relative emissivity measurements are being made on Cb-1Zr with various surface finishes and coating materials. In addition, specimens of Cb-1Zr with several coatings are being subjected to prolonged heating at 2200^{o}F in order to evaluate the coating stability and to determine the extent of reaction with the columbium alloy.

As part of the study of thermal conduction heating, a feasibility program on gas pressure, diffusion bonding of tantalum to alumina coated Cb-1Zr alloy specimens has been initiated with Battelle Memorial Institute personnel. The end product of this program will be a 6-inch long heater section which will be evaluated at FPLD during steady state operation and thermal cycling.

TEST SYSTEMS

300 KW Test System. The structural provisions and utility services for installation of this system are virtually complete. The major components are expected to be shipped in August by the vendors and erection will follow immediately. Some potential schedule problems have been identified and efforts made to assist the vendor with expediting as much as possible. The major delay appears to be associated with the piping subassemblies. The final run of 3-1/2 inch O.D. pipe had L-605 billets made up by Haynes which did not meet the ultrasonic specification requirements. It was necessary to obtain new billets and a several week delay can be anticipated in receipt of this tubing. Other components required for the subassemblies are under scrutiny to prevent delays.

Some additional fabrication by G.E. in lieu of subcontractors may help the schedule situation. As an example, the stand pipes for both the primary and secondary loop will be fabricated in the erection shop by G.E. rather than by Struthers Wells, the original vendor. These items are of simple geometry and the pieces can be readily fabricated at Evendale. The heater, pumps, and most of the valves are expected to be delivered in August. The throttle valves from Fisher-Governor appear to be a schedule problem and attention is being given to this item. These valves can be installed in the field rather than as part of the subassemblies. This would keep the delay in the facility completion to a minimum.

The electrical equipment and control panel is on schedule and some installation has been completed. The instrumentation items for readout are available from existing equipment and are being moved to the test cell. Checkout of this equipment will begin immediately, on completion of installation.

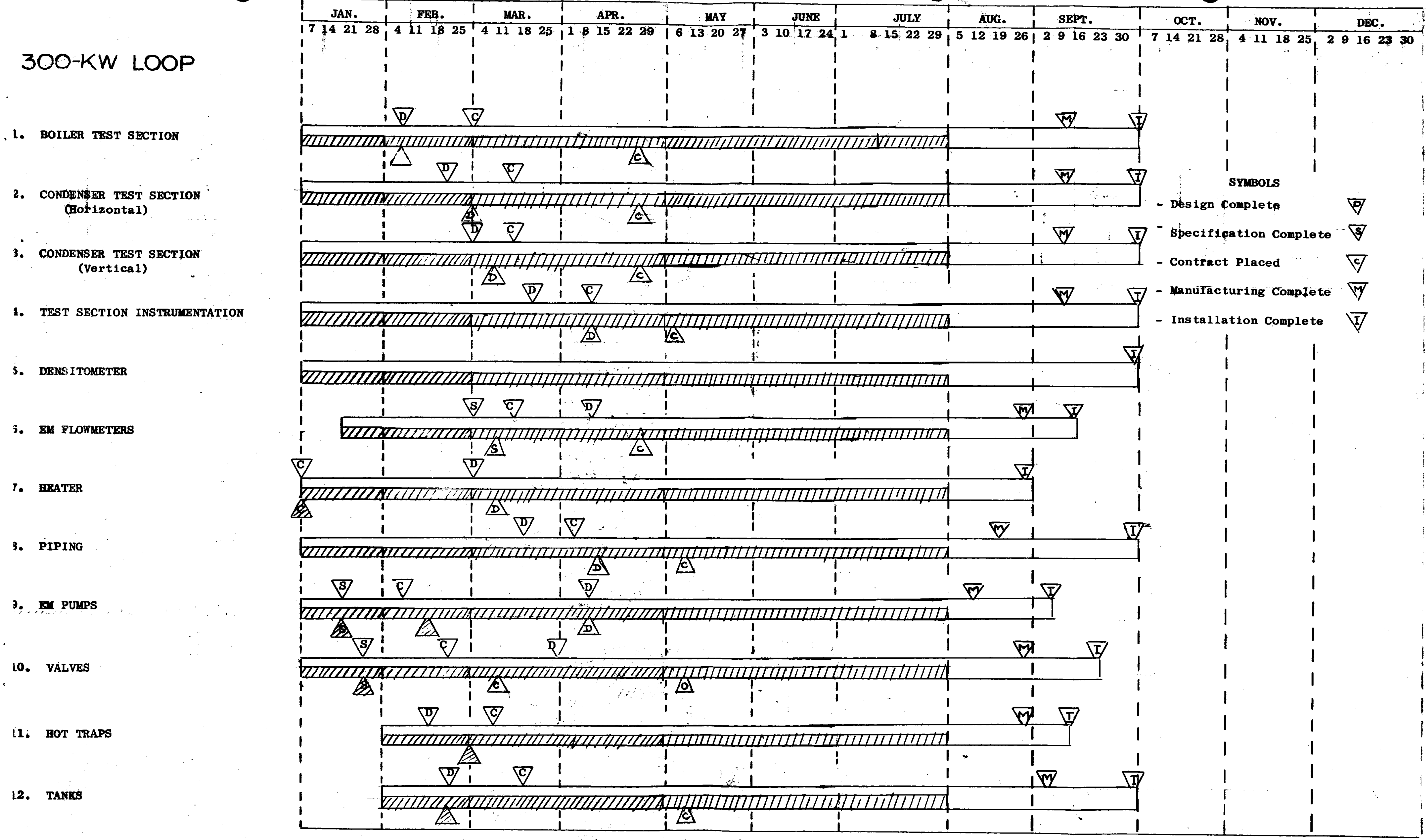
100 KW Test System. The design of this facility has been completed and the procurement of all components has been initiated. The project schedule indicates the items to be obtained and the current estimate of completion. The limiting item will be the vacuum tank and pumping equipment. This equipment is on order from National Research Corporation. Provision has been made to isolate the tank by a vacuum tight valve between the diffsuion pump and the mechanical pump to permit operation with inert gas if that appears most desirable. Tests are presently planned to give information on the most suitable environment for this test.

The test section development has continued on the direct electrical heated unit using diffusion bonding. Temperature measurement will consist of thermocouples attached to the walls of the tube and in a well in the mixing chamber at the discharge of the test section. A calibration well will also be provided for use with the brightness pyrometer. Pressure drop measurements will be made using a differential diaghragm type gage across the boiler tube.

The Cb-1Zr for the valves, piping, and accessories has been ordered from Wah Chang and is readily available. The bimetal joints to the stainless steel tank has been designed. Several sample joints will be fabricated and cycle tested prior to acceptance of the final joint.

50 KW Test System. All items of equipment for this test system are on hand and erection has been started. Provisions for 300 KW Test System instrumentation check out have been made. Some data on the 3/4 and 3/8 inch condensers should be obtained in August.

NAS 5-681 PROJECT SCHEDULE



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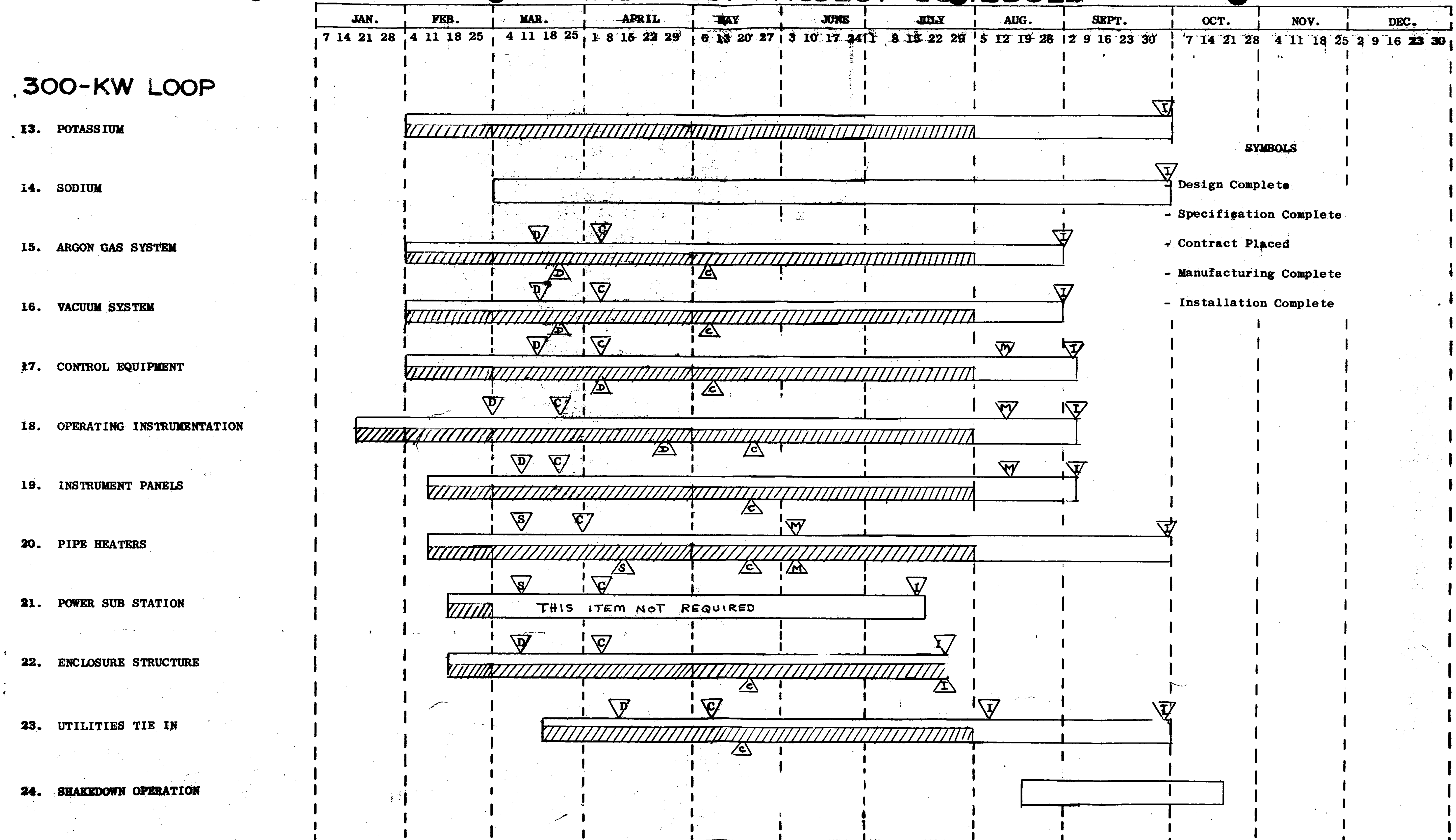

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